A PROJECT REPORT
ON

"ANALYSIS OF THIN BEAM SUBJECTED TO TRANSVERSE LOAD USING MATLAB AND ANSYS"

Submitted in partial fulfillment of the requirements

for the Finite Element Methods in Engineering (ME60407) of

Masters of Technology

in

Mechanical Systems Design (ME3)

Submitted By:

Piyush Kumar Nirmal	**(23ME63R07)**
Mungekar Gaurav Bholanath Madhavi	**(23ME63R11)**
Prabhat Kumar	**(23ME63R44)**

Under the Guidance of

Prof. Sanjay Gupta

DEPARTMENT OF MECHANICAL ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR, WEST BENGAL

Acknowledgement

Apart from my efforts, the success of the project depends largely on the encouragement and guidelines of many others. We take this opportunity to express my gratitude to the people who have been instrumental in the successful completion of this project.

I would like to express a deep sense of gratitude to the Prof. Sanjay Gupta for their cordial support as he gave the permission to use all required equipment/ license and the necessary material to complete the project.

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Finally, we also extend my heartiest thanks to our parents, friends, and well-wishers for being with us and extending encouragement throughout the project.

Declaration

I declare that this written submission represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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(Signature)
Piyush Kumar Nirmal
(23ME63R07)

(Signature)
Mungekar Gaurav Bholanath Madhavi
(23ME63R11)

(Signature)
Prabhat Kumar
(23ME63R44)

Date:

ABSTRACT

The finite element method is numerical analysis technique which gives approximate solutions to many of engineering problems. This project focuses on plain stress problem which is solved in MATLAB using Gauss Quadrature method. Gauss quadrature is widely used finite element method since it produces the most accurate numerical approximations possible. It which involves discretizing beam in number of quadrilateral elements (square shape in this case). Selection of number of elements is important to achieve close to accurate results, so we keep on increasing number of elements till we start getting repeating results. This is our verification step. The next step is validation of results which in done by solving same problem in ANSYS.

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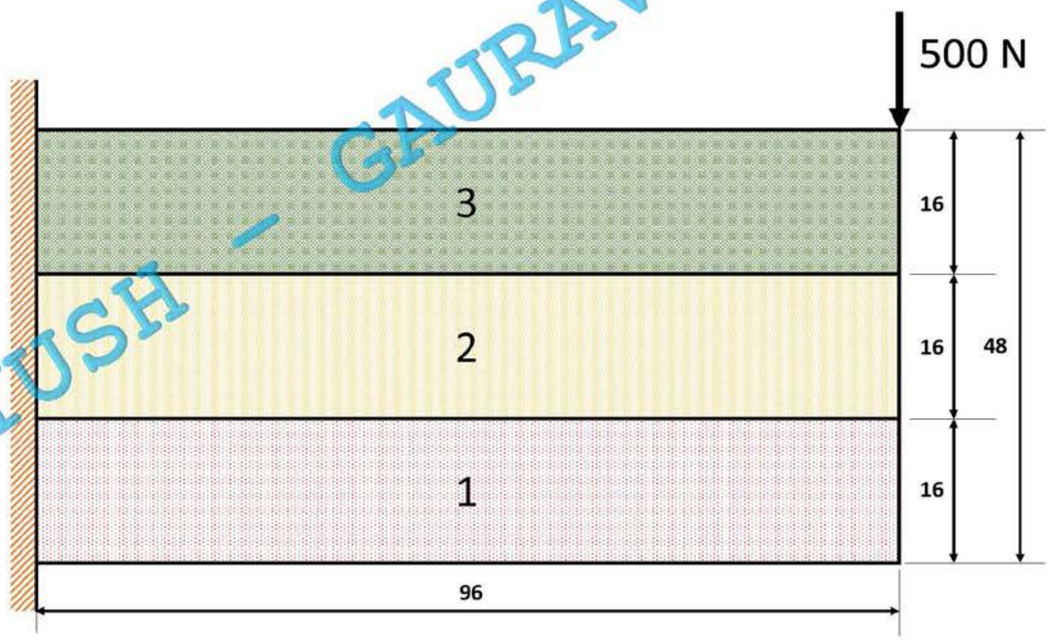
LIST OF FIGURES

CHAPTER 1

PROBLEM STATEMENT

Write a MATLAB code for the given beam made of three different materials subjected to transverse load of 500N using Finite Element Analysis.



(All dimensions are in mm)

Fig 1.1 Thin beam subjected to transverse load

The thickness of beam is 1 mm. E_1 = 25 GPa, E_2 = 50 GPa, E_3 = 100 GPa. Assume uniform Poisson's ratio as 0.3.

CHAPTER 2

OBJECTIVES

1) Find nodal displacement in X-direction and Y-direction.
2) Find nodal normal stresses (σ_{xx} and σ_{yy}) and shear stress (τ_{xy}).
3) Find nodal normal strains (ε_{xx} and ε_{yy}) and shear strain (γ_{xy}).
4) Plot contours of all the above results.
5) Compare results obtained from MATLAB and ANSYS and calculate percentage error.

CHAPTER 3

METHODOLOGY

3.1 Flowchart Showing Methodology Flow

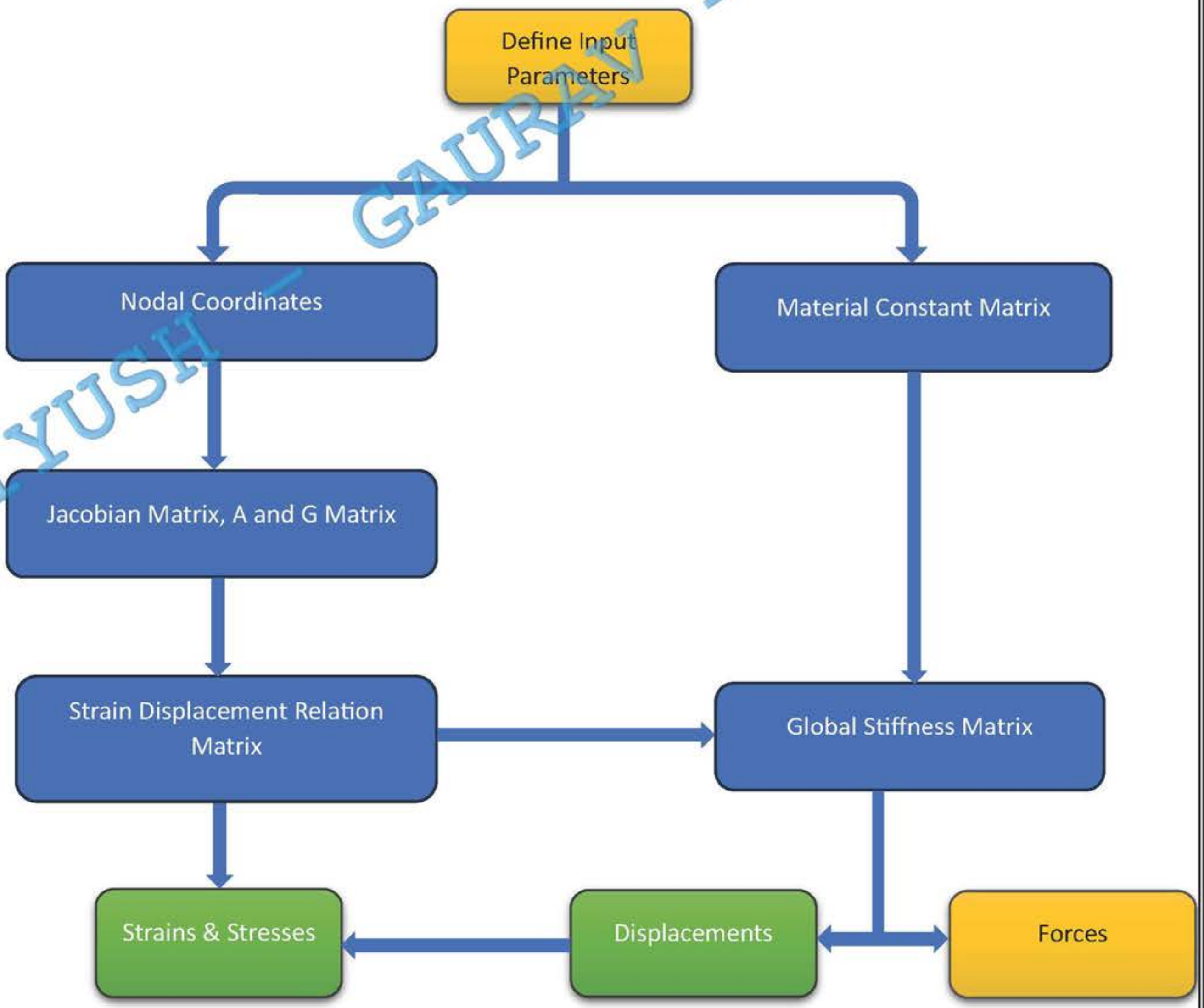


Fig 3.1 Flowchart Showing Methodology Flow for MATLAB

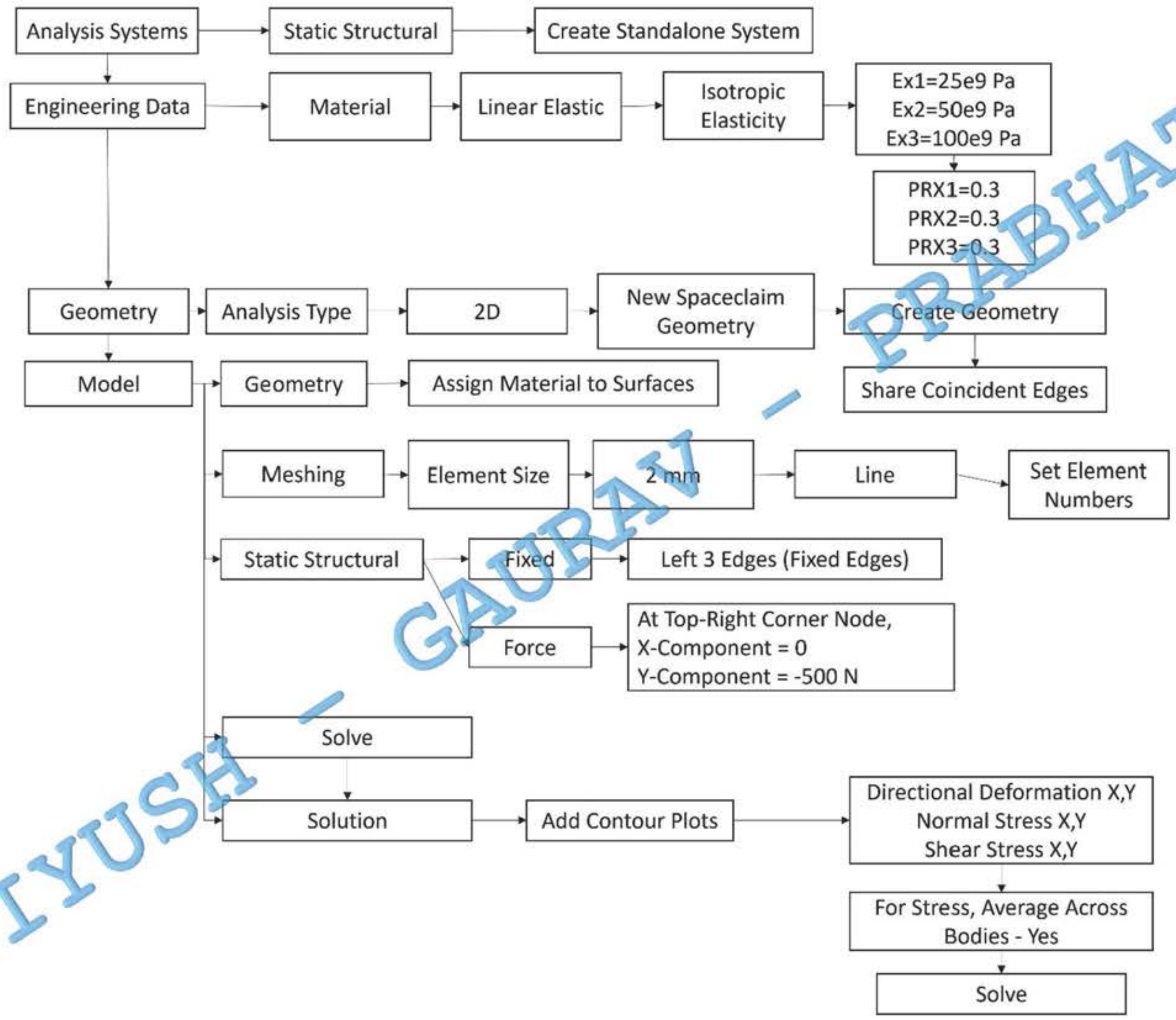


Fig 3.2 Flowchart Showing Methodology Flow for ANSYS Workbench 2022

3.2 Formulation

First step is to find global stiffness matrix for which initially we calculate Jacobian matrix. From Jacobian matrix, we calculate [A] matrix. Using shape functions of four-node element, we calculate [G] matrix.

Strain displacement matrix (B) is obtained by using [B] = [A] [G]. Material constant matrix is [D] matrix. Stiffness matrix at each gauss point is obtained by following relation

$Ka = [B]^{T} \cdot [D]. [B]. \det[J]. t$

Similarly, we find stiffness matrix at remaining three gauss points.

Then we sum it to get stiffness matrix of element

$K_i: = Ka + Kb + Kc + Kd$

By adding all element stiffness matrices at corresponding DOF we get global stiffness matrix [K].

Next step is to determine the nodal displacements [U] through the basic matrix equation

[F] = [K] [U]

Stress is obtained by using relation,

$[\sigma] = [D][B]$

All calculations in MATLAB are in mm and ANSYS calculation are in metres. For ANSYS Workbench 2022 R2 Software used. For MATLAB coding MATLAB 2022 is used.

3.3 MATLAB Commands

MATLAB Command	Use
setdiff	Set difference of two arrays
printf	Flexible support for printing list
meshgrid	Interpolating gridded data
reshape	Reshape array by rearranging existing element
contourf	Creates a filled contour plot
colorbar	Displays a vertical colorbar to the right of the current axes or chart
title	Adds the specified title to the current axes or standalone visualization
figure	Creates a new figure window using default property value

3.4 MATLAB Code

```
%%%%%%% Thin Beam Subjected to Point Load %%%%%%%
clc;
clear all;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%% Input Values %%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%
Lx = 96; %Total Length (mm)
Ly = 48; %Total Height (mm)
P = -500; %Point Load (N)
E1 = 25e3; E2 = 50e3; E3 = 100e3; %Young's Modulus (MPa)
E = [E1 E2 E3];
mu = 0.30; %Poisson's Ratio

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%% Mesh Generation %%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Number of Elements
numberElementsX = 48;
numberElementsY = 24;
numberElements = numberElementsX*numberElementsY;

% Element Size
deltaX = Lx/numberElementsX;
deltaY = Ly/numberElementsY;

% Total Nodes
nodesX = numberElementsX+1;
nodesY = numberElementsY+1;
numberNodes = nodesX*nodesY;

% GDof: global number of degrees of freedom
GDof = 2*numberNodes;

% nodal coordinates
node = [];
for j = 1:nodesY
    for i = 1:nodesX
        x = (i-1)*deltaX; y = (j-1)*deltaY;
        node = [node; x y];
    end
end

% connectivity
element = [];
for j = 1:numberElementsY
    for i = 1:numberElementsX
        i1 = i+(j-1)*nodesX;
        i2 = i1+1;
        i3 = i2+nodesX;
        i4 = i1+nodesX;
        element = [element; i1 i2 i3 i4];
    end
```

```
end

nodeCoordinates = node;
elementNodes = element;
xx = nodeCoordinates(:,1);
yy = nodeCoordinates(:,2);

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%% Global Stiffness Matrix %%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
stiffness = zeros(GDof);
thickness =1;

% Gauss point locations & Weights
gaussLocations = [ -0.577350269189626 -0.577350269189626;
                     0.577350269189626 -0.577350269189626;
                     0.577350269189626  0.577350269189626;
                    -0.577350269189626  0.577350269189626];
gaussWeights = [1;1;1;1];

for e = 1:numberElements
    indice = elementNodes(e,:);
    elementDof = [indice indice+numberNodes];
    ndof = length(indice);

        % cycle for Gauss point
    for q = 1:size(gaussWeights,1)
        GaussPoint = gaussLocations(q,:);
        xi = GaussPoint(1);
        eta = GaussPoint(2);

        % shape functions and derivatives
        shapeFunction = 1/4*[(1-xi)*(1-eta); (1+xi)*(1-eta);
            (1+xi)*(1+eta); (1-xi)*(1+eta)];

        naturalDerivatives = 1/4*[
            -(1-eta), -(1-xi); 1-eta,    -(1+xi);
            1+eta ,    1+xi; -(1+eta),  1-xi];

        % Jacobian Matrix
        Jacob = nodeCoordinates(indice,:)'*naturalDerivatives;
        invJacobian = inv(Jacob);
        XYderivatives = naturalDerivatives*invJacobian';


        % Strain Displacement matrix (B Matrix)
        B = zeros(3,2*ndof);
        B(1,1:ndof)          = XYderivatives(:,1)';
        B(2,ndof+1:2*ndof)   = XYderivatives(:,2)';
        B(3,1:ndof)          = XYderivatives(:,2)';
        B(3,ndof+1:2*ndof)   = XYderivatives(:,1)';

        % Material Matrix (D Matrix)
        if e <= numberElements/3
        D = E(1)/(1-mu^2)*[1 mu 0;mu 1 0;0 0 (1-mu)/2];
        elseif (numberElements/3 < e)&&(e <= 2*numberElements/3)
        D = E(2)/(1-mu^2)*[1 mu 0;mu 1 0;0 0 (1-mu)/2];
        elseif (2*numberElements/3 < e)&&(e <= numberElements)
        D = E(3)/(1-mu^2)*[1 mu 0;mu 1 0;0 0 (1-mu)/2];
```

```
        end

        % Element stiffness matrix at Particular Gauss Point (K Matrix)
        stiffness(elementDof,elementDof) = ...
            stiffness(elementDof,elementDof) + ...
            B'*D*B*thickness*gaussWeights(q)*det(Jacob);
    end

 end

% Boundary Conditions
fixedNodeX = find(nodeCoordinates(:,1)==0);  % fixed in XX
fixedNodeY = find(nodeCoordinates(:,1)==0);  % fixed in YY
prescribedDof = [fixedNodeX; fixedNodeY+numberNodes];

% Force vector (Point load applied at Beam End)
force = zeros(GDof,1);
force(2*numberNodes) = P;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%% Displacement Vector %%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

activeDof = setdiff((1:GDof)', prescribedDof);
stiffnessactive = stiffness(activeDof,activeDof);
U = stiffness(activeDof,activeDof)\force(activeDof);
displacements = zeros(GDof,1);
displacements(activeDof) = U;

% Displacement Print
disp('Displacements')
jj = 1:GDof; format("default")
f = [jj; displacements'];
fprintf('node U\n')
fprintf('%3d %12.8f\n',f)
UX = displacements(1:numberNodes);
UY = displacements(numberNodes+1:GDof);

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%% Stress Matrix at Nodes %%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
nodeLocations = [-1 -1;1 -1;1 1;-1 1];
stressExtr = zeros(numberElements,size(nodeLocations,1),3);
strainExtraaa = zeros(numberElements,size(nodeLocations,1),3);

for e = 1:numberElements
    indice3 = elementNodes(e,:);
    elementDof2 = [ indice3 indice3+numberNodes ];
    nn = length(indice3);

    for q = 1:size(gaussWeights,1)
        pt = nodeLocations(q,:);
        xi = pt(1);
        eta = pt(2);

        % shape functions and derivatives
        shapeFunction = 1/4*[(1-xi)*(1-eta); (1+xi)*(1-eta);
            (1+xi)*(1+eta); (1-xi)*(1+eta)];
```

```
        naturalDerivatives = 1/4*[
            -(1-eta), -(1-xi); 1-eta,   -(1+xi);
            1+eta ,    1+xi; -(1+eta),  1-xi];

        % Jacobian Matrix
        Jacob = nodeCoordinates(indice3,:)'*naturalDerivatives;
        invJacobian = inv(Jacob);
        XYderivatives = naturalDerivatives*invJacobian';

        % Material Matrix (D Matrix)
        if e <= numberElements/3
        D = E(1)/(1-mu^2)*[1 mu 0;mu 1 0;0 0 (1-mu)/2];
        elseif (numberElements/3 < e)&&(e <= 2*numberElements/3)
        D = E(2)/(1-mu^2)*[1 mu 0;mu 1 0;0 0 (1-mu)/2];
        elseif (2*numberElements/3 < e)&&(e <= numberElements)
        D = E(3)/(1-mu^2)*[1 mu 0;mu 1 0;0 0 (1-mu)/2];
        end

        %  B matrix
        B = zeros(3,2*nn);
        B(1,1:nn)       = XYderivatives(:,1)';
        B(2,nn+1:2*nn)  = XYderivatives(:,2)';
        B(3,1:nn)       = XYderivatives(:,2)';
        B(3,nn+1:2*nn)  = XYderivatives(:,1)';

        % Strain Vector (at Nodes)
        strainExtr = B*displacements(elementDof2);
        strainExtraaa(e,q,:) = strainExtr;
        % Stress Vector (at Nodes)
        stressExtr(e,q,:) = D*strainExtr;
    end
end

% stress averaging at nodes
stressAvg = zeros(numberNodes,3);
for i = 1:3
    currentStress = stressExtr(:,:,i);
    for n = 1:numberNodes
        idx = find(n==elementNodes);
            stressAvg(n,i) = sum(currentStress(idx))/length(currentStress(idx));
    end
end

% strain averaging at nodes
strainAvg = zeros(numberNodes,3);
for i = 1:3
    currentStrain = strainExtraaa(:,:,i);
    for n = 1:numberNodes
        idx = find(n==elementNodes);
            strainAvg(n,i) = sum(currentStrain(idx))/length(currentStrain(idx));
    end
end

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%% Displacements Contours %%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
[X,Y]=meshgrid(0:deltaX:Lx,0:deltaY:Ly);
displacementsxx_raw=displacements(1:end/2);
displacementsyy_raw=displacements(end/2+1:end);
```

```
displacementsxx=reshape(displacementsxx_raw,numberElementsX+1,numberElementsY+1);
displacementsyy=reshape(displacementsyy_raw,numberElementsX+1,numberElementsY+1);
figure;
displacementsxx_contour = contourf(X,Y,displacementsxx','edgecolor','none');
shading interp
colorbar
title('Displacement xx Contour')
axis equal
figure;
displacementsyy_contour = contourf(X,Y,displacementsyy','edgecolor','none');
shading interp
colorbar
title('Displacement yy Contour')
axis equal


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%% Stress Contours %%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

[X,Y]=meshgrid(0:deltaX:Lx,0:deltaY:Ly);
Stressmesh1xx_raw=stressAvg(:,1);
Stressmesh1yy_raw=stressAvg(:,2);
Stressmesh1xy_raw=stressAvg(:,3);
Stressmesh1xx=reshape(Stressmesh1xx_raw,numberElementsX+1,numberElementsY+1);
Stressmesh1yy=reshape(Stressmesh1yy_raw,numberElementsX+1,numberElementsY+1);
Stressmesh1xy=reshape(Stressmesh1xy_raw,numberElementsX+1,numberElementsY+1);
figure;
Stressmesh1xx_contour = contourf(X,Y,Stressmesh1xx','edgecolor','none');
shading interp
colorbar
title('Stress σxx Contour')
axis equal
figure;
Stressmesh1yy_contour = contourf(X,Y,Stressmesh1yy','edgecolor','none');
shading interp
colorbar
title('Stress σyy Contour')
axis equal
figure;
Stressmesh1xy_contour = contourf(X,Y,Stressmesh1xy','edgecolor','none');
shading interp
colorbar
title('Stress τxy Contour')
axis equal

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%% Strain Contours %%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

[X,Y]=meshgrid(0:deltaX:Lx,0:deltaY:Ly);
Strainmesh1xx_raw=strainAvg(:,1);
Strainmesh1yy_raw=strainAvg(:,2);
Strainmesh1xy_raw=strainAvg(:,3);
Strainmesh1xx=reshape(Strainmesh1xx_raw,numberElementsX+1,numberElementsY+1);
Strainmesh1yy=reshape(Strainmesh1yy_raw,numberElementsX+1,numberElementsY+1);
Strainmesh1xy=reshape(Strainmesh1xy_raw,numberElementsX+1,numberElementsY+1);
figure;
Strainmesh1xx_contour = contourf(X,Y,Strainmesh1xx','edgecolor','none');
```

```
shading interp
colorbar
title('Strain εxx Contour')
axis equal
figure;
Strainmesh1yy_contour = contourf(X,Y,Strainmesh1yy','edgecolor','none');
shading interp
colorbar
title('Strain εyy Contour')
axis equal
figure;
Strainmesh1xy_contour = contourf(X,Y,Strainmesh1xy','edgecolor','none');
shading interp
colorbar
title('Strain γxy Contour')
axis equal
```

CHAPTER 4

RESULT TABLES AND CONTOURS

4.1 Results Comparison

(1) Displacements Results Comparison in MATLAB and ANSYS at Interface:

Node Number (MATLAB)	Node Number (ANSYS)	DispX (mm) (MATLAB)	DispX (mm) (ANSYS)	DispX Error (%)	DispY (mm) (MATLAB)	DispY (mm) (ANSYS)	DispY Error (%)
393	58	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
394	105	-0.003004	-0.003004	0.000470	-0.001680	-0.001680	0.001903
395	104	-0.005905	-0.005905	0.000316	-0.003525	-0.003525	0.000592
396	103	-0.008781	-0.008781	0.000328	-0.005775	-0.005775	0.000264
397	102	-0.011648	-0.011648	0.004174	-0.008428	-0.008428	0.000318
398	101	-0.014503	-0.014503	0.001663	-0.011481	-0.011481	0.002443
399	100	-0.017333	-0.017333	0.000382	-0.014920	-0.014920	0.001488
400	99	-0.020128	-0.020128	0.000730	-0.018733	-0.018733	0.000010
401	98	-0.022878	-0.022878	0.000626	-0.022909	-0.022909	0.002056
402	97	-0.025574	-0.025574	0.000142	-0.027440	-0.027440	0.000736
403	96	-0.028210	-0.028210	0.000976	-0.032316	-0.032316	0.000902
404	95	-0.030782	-0.030782	0.001353	-0.037530	-0.037530	0.001104
405	94	-0.033287	-0.033287	0.001449	-0.043074	-0.043074	0.000246
406	93	-0.035724	-0.035724	0.000881	-0.048942	-0.048942	0.000021
407	92	-0.038090	-0.038090	0.000123	-0.055126	-0.055126	0.000265
408	91	-0.040386	-0.040386	0.000391	-0.061618	-0.061618	0.000217
409	90	-0.042612	-0.042612	0.000014	-0.068411	-0.068411	0.000087
410	89	-0.044768	-0.044768	0.000480	-0.075497	-0.075497	0.000458
411	88	-0.046854	-0.046854	0.000164	-0.082867	-0.082867	0.000289
412	87	-0.048871	-0.048871	0.000208	-0.090513	-0.090513	0.000070
413	86	-0.050819	-0.050819	0.000507	-0.098427	-0.098427	0.000127
414	85	-0.052700	-0.052700	0.000808	-0.106600	-0.106600	0.000385
415	84	-0.054512	-0.054512	0.000784	-0.115024	-0.115020	0.003747
416	83	-0.056258	-0.056258	0.000679	-0.123690	-0.123690	0.000125
417	82	-0.057938	-0.057938	0.000042	-0.132589	-0.132590	0.000586
418	81	-0.059552	-0.059552	0.000514	-0.141713	-0.141710	0.001928
419	80	-0.061100	-0.061100	0.000087	-0.151052	-0.151050	0.001210
420	79	-0.062583	-0.062583	0.000055	-0.160598	-0.160600	0.001529
421	78	-0.064001	-0.064001	0.000160	-0.170341	-0.170340	0.000447
422	77	-0.065354	-0.065354	0.000134	-0.180272	-0.180270	0.001182
423	76	-0.066642	-0.066642	0.000534	-0.190382	-0.190380	0.001039

424	75	-0.067863	-0.067863	0.000087	-0.200660	-0.200660	0.000090
425	74	-0.069017	-0.069017	0.000221	-0.211096	-0.211100	0.001898
426	73	-0.070102	-0.070102	0.000233	-0.221678	-0.221680	0.000974
427	72	-0.071116	-0.071116	0.000513	-0.232393	-0.232390	0.001308
428	71	-0.072054	-0.072054	0.000429	-0.243227	-0.243230	0.001043
429	70	-0.072914	-0.072914	0.000063	-0.254165	-0.254170	0.001910
430	69	-0.073690	-0.073690	0.000263	-0.265188	-0.265190	0.000834
431	68	-0.074376	-0.074376	0.000350	-0.276274	-0.276270	0.001536
432	67	-0.074965	-0.074965	0.000571	-0.287400	-0.287400	0.000025
433	66	-0.075452	-0.075452	0.000465	-0.298536	-0.298540	0.001245
434	65	-0.075831	-0.075831	0.000463	-0.309650	-0.309650	0.000104
435	64	-0.076096	-0.076096	0.000321	-0.320704	-0.320700	0.001364
436	63	-0.076248	-0.076248	0.000463	-0.331656	-0.331660	0.001145
437	62	-0.076291	-0.076291	0.000469	-0.342460	-0.342460	0.000111
438	61	-0.076237	-0.076237	0.000149	-0.353066	-0.353070	0.001204
439	60	-0.076106	-0.076106	0.000492	-0.363425	-0.363420	0.001274
440	59	-0.075929	-0.075929	0.000567	-0.373487	-0.373490	0.000832
441	50	-0.075743	-0.075743	0.000277	-0.383181	-0.383180	0.000362
785	450	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
786	497	-0.000125	-0.000125	0.003818	-0.000565	-0.000565	0.000393
787	496	-0.000218	-0.000218	0.002242	-0.001760	-0.001760	0.000086
788	495	-0.000267	-0.000267	0.000494	-0.003544	-0.003544	0.000647
789	494	-0.000272	-0.000272	0.001245	-0.005870	-0.005870	0.000771
790	493	-0.000238	-0.000238	0.000375	-0.008695	-0.008695	0.000325
791	492	-0.000170	-0.000170	0.002310	-0.011982	-0.011982	0.000690
792	491	-0.000077	-0.000077	0.000275	-0.015702	-0.015702	0.001792
793	490	0.000035	0.000035	0.000412	-0.019832	-0.019832	0.001285
794	489	0.000161	0.000161	0.001616	-0.024351	-0.024351	0.000601
795	488	0.000296	0.000296	0.001082	-0.029244	-0.029244	0.000863
796	487	0.000436	0.000437	0.000269	-0.034497	-0.034497	0.000223
797	486	0.000581	0.000581	0.000569	-0.040096	-0.040096	0.001040
798	485	0.000727	0.000727	0.000662	-0.046031	-0.046031	0.000135
799	484	0.000873	0.000873	0.000472	-0.052289	-0.052289	0.000663
800	483	0.001019	0.001019	0.001109	-0.058861	-0.058861	0.000039
801	482	0.001164	0.001164	0.001315	-0.065736	-0.065736	0.000734
802	481	0.001306	0.001306	0.000399	-0.072903	-0.072903	0.000092
803	480	0.001446	0.001446	0.001754	-0.080353	-0.080353	0.000508
804	479	0.001582	0.001582	0.001887	-0.088077	-0.088077	0.000355
805	478	0.001714	0.001714	0.001822	-0.096065	-0.096065	0.000180
806	477	0.001841	0.001841	0.001769	-0.104308	-0.104310	0.002247
807	476	0.001962	0.001962	0.000062	-0.112796	-0.112800	0.003934
808	475	0.002077	0.002077	0.001853	-0.121520	-0.121520	0.000144
809	474	0.002185	0.002185	0.000682	-0.130472	-0.130470	0.001157
810	473	0.002284	0.002284	0.001041	-0.139642	-0.139640	0.001316
811	472	0.002374	0.002374	0.001334	-0.149022	-0.149020	0.001479
812	471	0.002454	0.002454	0.001216	-0.158604	-0.158600	0.002652
813	470	0.002521	0.002522	0.000675	-0.168380	-0.168380	0.000183
814	469	0.002576	0.002576	0.000493	-0.178341	-0.178340	0.000451

815	468	0.002614	0.002614	0.001062	-0.188480	-0.188480	0.000033
816	467	0.002636	0.002636	0.000302	-0.198790	-0.198790	0.000220
817	466	0.002637	0.002637	0.000025	-0.209265	-0.209270	0.002170
818	465	0.002617	0.002617	0.001595	-0.219899	-0.219900	0.000296
819	464	0.002572	0.002572	0.000767	-0.230687	-0.230690	0.001230
820	463	0.002500	0.002500	0.000579	-0.241625	-0.241620	0.002052
821	462	0.002398	0.002398	0.001660	-0.252710	-0.252710	0.000023
822	461	0.002265	0.002265	0.000343	-0.263941	-0.263940	0.000208
823	460	0.002100	0.002100	0.000344	-0.275316	-0.275320	0.001331
824	459	0.001907	0.001907	0.002111	-0.286837	-0.286840	0.000887
825	458	0.001691	0.001691	0.001308	-0.298503	-0.298500	0.001096
826	457	0.001468	0.001468	0.003401	-0.310310	-0.310310	0.000161
827	456	0.001258	0.001258	0.001606	-0.322243	-0.322240	0.000916
828	455	0.001097	0.001097	0.001243	-0.334273	-0.334270	0.000955
829	454	0.001025	0.001025	0.003565	-0.346342	-0.346340	0.000451
830	453	0.001085	0.001085	0.001411	-0.358350	-0.358350	0.000104
831	452	0.001304	0.001304	0.002529	-0.370158	-0.370160	0.000608
832	451	0.001672	0.001672	0.000222	-0.381584	-0.381580	0.001165
833	442	0.002139	0.002139	0.000368	-0.392379	-0.392380	0.000323
Avg:				0.000850			0.000839

(2) Nodal Stress Results Comparison in MATLAB and ANSYS at Interface:

Node Number (MAT)	σxx (MPa) (MAT)	σxx (MPa) (ANSYS)	σxx Error (%)	σyy (MPa) (MAT)	σyy (MPa) (ANSYS)	σyy Error (%)	τxy (MPa) (MAT)	τxy (MPa) (ANSYS)	τxy Error (%)
393	-61.8938	-61.8940	0.0003	-18.5682	-18.5685	0.0019	-12.1144	-12.1147	0.0018
394	-59.0807	-59.0805	0.0004	-12.4176	-12.4180	0.0033	-9.5119	-9.5122	0.0022
395	-57.1130	-57.1130	0.0000	-9.8561	-9.8561	0.0003	-9.0870	-9.0870	0.0000
396	-56.1475	-56.1480	0.0009	-7.6614	-7.6614	0.0002	-9.4606	-9.4607	0.0010
397	-55.3886	-55.3885	0.0001	-5.8101	-5.8101	0.0007	-9.7367	-9.7368	0.0005
398	-54.5670	-54.5670	0.0000	-4.2469	-4.2469	0.0010	-9.9033	-9.9032	0.0020
399	-53.6336	-53.6335	0.0002	-2.9853	-2.9853	0.0001	-9.9724	-9.9722	0.0018
400	-52.5844	-52.5840	0.0008	-2.0068	-2.0068	0.0004	-9.9825	-9.9825	0.0000
401	-51.4371	-51.4370	0.0001	-1.2751	-1.2751	0.0016	-9.9663	-9.9665	0.0021
402	-50.2152	-50.2155	0.0007	-0.7458	-0.7458	0.0013	-9.9463	-9.9466	0.0024
403	-48.9418	-48.9415	0.0005	-0.3751	-0.3751	0.0032	-9.9353	-9.9352	0.0014
404	-47.6361	-47.6360	0.0002	-0.1242	-0.1242	0.0086	-9.9389	-9.9391	0.0018
405	-46.3127	-46.3125	0.0005	0.0389	0.0389	0.0152	-9.9582	-9.9583	0.0004
406	-44.9821	-44.9820	0.0001	0.1399	0.1399	0.0142	-9.9920	-9.9919	0.0015
407	-43.6511	-43.6510	0.0002	0.1986	0.1986	0.0090	-10.0381	-10.0381	0.0004
408	-42.3243	-42.3240	0.0008	0.2297	0.2297	0.0055	-10.0937	-10.0936	0.0013
409	-41.0044	-41.0045	0.0002	0.2444	0.2444	0.0037	-10.1568	-10.1568	0.0002
410	-39.6928	-39.6930	0.0004	0.2509	0.2508	0.0023	-10.2254	-10.2252	0.0023
411	-38.3903	-38.3905	0.0006	0.2548	0.2548	0.0030	-10.2983	-10.2983	0.0002
412	-37.0969	-37.0970	0.0002	0.2603	0.2603	0.0073	-10.3749	-10.3749	0.0002
413	-35.8128	-35.8125	0.0007	0.2703	0.2703	0.0010	-10.4549	-10.4549	0.0004
414	-34.5375	-34.5375	0.0000	0.2865	0.2865	0.0004	-10.5385	-10.5386	0.0008
415	-33.2708	-33.2705	0.0009	0.3100	0.3100	0.0013	-10.6262	-10.6260	0.0023
416	-32.0122	-32.0125	0.0010	0.3412	0.3412	0.0003	-10.7190	-10.7190	0.0004
417	-30.7609	-30.7610	0.0002	0.3795	0.3795	0.0004	-10.8175	-10.8175	0.0004
418	-29.5162	-29.5165	0.0009	0.4242	0.4242	0.0005	-10.9229	-10.9230	0.0007
419	-28.2768	-28.2770	0.0005	0.4732	0.4732	0.0033	-11.0360	-11.0360	0.0002
420	-27.0411	-27.0410	0.0004	0.5241	0.5241	0.0020	-11.1574	-11.1570	0.0034
421	-25.8067	-25.8065	0.0008	0.5731	0.5731	0.0002	-11.2874	-11.2875	0.0005
422	-24.5705	-24.5705	0.0000	0.6152	0.6152	0.0024	-11.4259	-11.4260	0.0006
423	-23.3284	-23.3285	0.0006	0.6442	0.6442	0.0010	-11.5719	-11.5720	0.0012
424	-22.0748	-22.0745	0.0016	0.6518	0.6518	0.0001	-11.7232	-11.7235	0.0027
425	-20.8031	-20.8030	0.0006	0.6283	0.6283	0.0003	-11.8764	-11.8765	0.0007
426	-19.5048	-19.5050	0.0010	0.5616	0.5616	0.0001	-12.0263	-12.0265	0.0021
427	-18.1700	-18.1700	0.0000	0.4379	0.4379	0.0001	-12.1650	-12.1650	0.0002
428	-16.7876	-16.7880	0.0024	0.2417	0.2417	0.0008	-12.2819	-12.2815	0.0029
429	-15.3459	-15.3460	0.0008	-0.0436	-0.0436	0.0049	-12.3625	-12.3625	0.0002
430	-13.8338	-13.8338	0.0002	-0.4348	-0.4348	0.0007	-12.3882	-12.3885	0.0021
431	-12.2430	-12.2429	0.0011	-0.9468	-0.9468	0.0010	-12.3354	-12.3355	0.0010
432	-10.5704	-10.5701	0.0024	-1.5904	-1.5905	0.0013	-12.1751	-12.1755	0.0030
433	-8.8222	-8.8224	0.0018	-2.3693	-2.3693	0.0002	-11.8737	-11.8735	0.0015

434	-7.0192	-7.0192	0.0003	-3.2757	-3.2758	0.0008	-11.3931	-11.3930	0.0006
435	-5.2020	-5.2020	0.0005	-4.2867	-4.2867	0.0008	-10.6932	-10.6935	0.0031
436	-3.4374	-3.4374	0.0007	-5.3606	-5.3607	0.0005	-9.7348	-9.7347	0.0015
437	-1.8240	-1.8240	0.0003	-6.4382	-6.4382	0.0002	-8.4844	-8.4845	0.0003
438	-0.4943	-0.4943	0.0003	-7.4518	-7.4518	0.0006	-6.9183	-6.9184	0.0006
439	0.3717	0.3717	0.0042	-8.3691	-8.3691	0.0004	-5.0272	-5.0273	0.0004
440	0.6224	0.6224	0.0008	-9.2639	-9.2637	0.0025	-2.7354	-2.7355	0.0004
441	0.0925	0.0925	0.0013	-11.3568	-11.3568	0.0002	-1.5413	-1.5413	0.0006
785	-5.1369	-5.1369	0.0005	-1.5411	-1.5411	0.0008	-8.1460	-8.1459	0.0016
786	-3.7844	-3.7845	0.0008	0.9862	0.9862	0.0023	-7.0427	-7.0427	0.0004
787	-2.2699	-2.2699	0.0002	1.3259	1.3259	0.0010	-10.0983	-10.0983	0.0002
788	-0.6708	-0.6709	0.0037	1.1884	1.1884	0.0006	-12.4448	-12.4450	0.0013
789	0.8066	0.8066	0.0004	0.8787	0.8788	0.0019	-14.1143	-14.1140	0.0024
790	2.0850	2.0851	0.0011	0.5719	0.5719	0.0059	-15.2444	-15.2445	0.0007
791	3.1180	3.1180	0.0012	0.3315	0.3315	0.0010	-15.9758	-15.9760	0.0013
792	3.9079	3.9079	0.0008	0.1696	0.1696	0.0099	-16.4315	-16.4315	0.0002
793	4.4855	4.4856	0.0001	0.0743	0.0743	0.0038	-16.7045	-16.7045	0.0003
794	4.8921	4.8921	0.0004	0.0265	0.0265	0.1120	-16.8591	-16.8590	0.0009
795	5.1671	5.1671	0.0008	0.0084	0.0085	0.1164	-16.9377	-16.9375	0.0012
796	5.3433	5.3433	0.0003	0.0065	0.0066	0.4363	-16.9671	-16.9670	0.0003
797	5.4455	5.4455	0.0001	0.0119	0.0119	0.0629	-16.9644	-16.9645	0.0005
798	5.4916	5.4915	0.0002	0.0196	0.0196	0.1477	-16.9409	-16.9410	0.0007
799	5.4936	5.4936	0.0005	0.0275	0.0275	0.0718	-16.9038	-16.9035	0.0017
800	5.4602	5.4602	0.0002	0.0355	0.0355	0.0392	-16.8581	-16.8580	0.0005
801	5.3966	5.3966	0.0006	0.0446	0.0447	0.0032	-16.8070	-16.8070	0.0002
802	5.3066	5.3067	0.0009	0.0568	0.0568	0.0085	-16.7528	-16.7530	0.0013
803	5.1922	5.1922	0.0005	0.0740	0.0740	0.0272	-16.6967	-16.6965	0.0010
804	5.0546	5.0546	0.0003	0.0983	0.0984	0.0055	-16.6394	-16.6395	0.0007
805	4.8940	4.8940	0.0002	0.1319	0.1320	0.0004	-16.5812	-16.5810	0.0015
806	4.7099	4.7099	0.0001	0.1767	0.1767	0.0076	-16.5222	-16.5220	0.0012
807	4.5010	4.5010	0.0001	0.2342	0.2343	0.0110	-16.4620	-16.4620	0.0002
808	4.2653	4.2653	0.0004	0.3060	0.3060	0.0047	-16.4005	-16.4005	0.0002
809	3.9999	3.9999	0.0001	0.3930	0.3930	0.0021	-16.3372	-16.3370	0.0013
810	3.7009	3.7009	0.0007	0.4960	0.4960	0.0034	-16.2721	-16.2725	0.0023
811	3.3637	3.3637	0.0003	0.6152	0.6152	0.0020	-16.2053	-16.2055	0.0012
812	2.9822	2.9823	0.0001	0.7501	0.7501	0.0003	-16.1373	-16.1370	0.0016
813	2.5495	2.5495	0.0001	0.8994	0.8994	0.0003	-16.0691	-16.0690	0.0004
814	2.0571	2.0571	0.0001	1.0604	1.0604	0.0011	-16.0026	-16.0025	0.0007
815	1.4955	1.4955	0.0015	1.2290	1.2290	0.0012	-15.9409	-15.9410	0.0005
816	0.8540	0.8540	0.0008	1.3983	1.3983	0.0008	-15.8885	-15.8885	0.0002
817	0.1213	0.1213	0.0001	1.5583	1.5583	0.0012	-15.8521	-15.8520	0.0007
818	-0.7138	-0.7138	0.0032	1.6943	1.6943	0.0001	-15.8411	-15.8410	0.0007
819	-1.6607	-1.6607	0.0001	1.7848	1.7848	0.0009	-15.8687	-15.8685	0.0010
820	-2.7239	-2.7240	0.0001	1.7989	1.7989	0.0007	-15.9526	-15.9525	0.0007
821	-3.8988	-3.8988	0.0002	1.6919	1.6919	0.0005	-16.1163	-16.1160	0.0019
822	-5.1631	-5.1631	0.0002	1.4001	1.4001	0.0008	-16.3887	-16.3885	0.0015
823	-6.4660	-6.4660	0.0001	0.8321	0.8321	0.0006	-16.8027	-16.8025	0.0009
824	-7.7123	-7.7124	0.0010	-0.1408	-0.1408	0.0013	-17.3882	-17.3885	0.0015

825	-8.7459	-8.7457	0.0021	-1.6973	-1.6973	0.0004	-18.1583	-18.1585	0.0013
826	-9.3404	-9.3403	0.0006	-4.0756	-4.0756	0.0002	-19.0789	-19.0790	0.0007
827	-9.2171	-9.2174	0.0023	-7.5715	-7.5715	0.0004	-20.0219	-20.0220	0.0003
828	-8.1183	-8.1184	0.0002	-12.5022	-12.5020	0.0014	-20.7044	-20.7045	0.0005
829	-5.9545	-5.9545	0.0003	-19.1090	-19.1090	0.0002	-20.6442	-20.6440	0.0011
830	-3.0010	-3.0011	0.0005	-27.3991	-27.3990	0.0004	-19.1874	-19.1875	0.0005
831	-0.1256	-0.1256	0.0291	-37.0698	-37.0695	0.0008	-15.6653	-15.6655	0.0011
832	1.3736	1.3736	0.0011	-47.6168	-47.6170	0.0005	-9.2788	-9.2789	0.0002
833	-1.2720	-1.2720	0.0028	-62.6384	-62.6385	0.0001	-5.9219	-5.9219	0.0001
Avg:			**0.0010**			**0.0124**			**0.0010**

(3) Nodal Strain Results Comparison in MATLAB and ANSYS at Interface:

Node	εxx (MAT)	εxx (ANSYS)	εxx Error (%)	εyy (MAT)	εyy (ANSYS)	εyy Error (%)	γxy (MAT)	γxy (ANSYS)	γxy Error (%)
393	-0.0015	-0.0015	0.0029	0.0000	0.0000	0.0000	-0.0008	-0.0008	0.0005
394	-0.0015	-0.0015	0.0031	0.0001	0.0001	0.0009	-0.0007	-0.0007	0.0003
395	-0.0014	-0.0014	0.0025	0.0002	0.0002	0.0013	-0.0007	-0.0007	0.0003
396	-0.0014	-0.0014	0.0017	0.0002	0.0002	0.0011	-0.0007	-0.0007	0.0002
397	-0.0014	-0.0014	0.0033	0.0003	0.0003	0.0003	-0.0007	-0.0007	0.0000
398	-0.0014	-0.0014	0.0032	0.0003	0.0003	0.0001	-0.0008	-0.0008	0.0002
399	-0.0014	-0.0014	0.0033	0.0004	0.0004	0.0002	-0.0008	-0.0008	0.0001
400	-0.0014	-0.0014	0.0002	0.0004	0.0004	0.0001	-0.0008	-0.0008	0.0001
401	-0.0014	-0.0014	0.0034	0.0004	0.0004	0.0002	-0.0008	-0.0008	0.0000
402	-0.0013	-0.0013	0.0003	0.0004	0.0004	0.0007	-0.0008	-0.0008	0.0005
403	-0.0013	-0.0013	0.0010	0.0004	0.0004	0.0003	-0.0008	-0.0008	0.0001
404	-0.0013	-0.0013	0.0001	0.0004	0.0004	0.0003	-0.0008	-0.0008	0.0000
405	-0.0012	-0.0012	0.0014	0.0004	0.0004	0.0005	-0.0008	-0.0008	0.0005
406	-0.0012	-0.0012	0.0034	0.0004	0.0004	0.0005	-0.0008	-0.0008	0.0006
407	-0.0012	-0.0012	0.0016	0.0004	0.0004	0.0003	-0.0008	-0.0008	0.0002
408	-0.0011	-0.0011	0.0012	0.0004	0.0004	0.0004	-0.0008	-0.0008	0.0006
409	-0.0011	-0.0011	0.0006	0.0003	0.0003	0.0007	-0.0008	-0.0008	0.0001
410	-0.0011	-0.0011	0.0017	0.0003	0.0003	0.0014	-0.0008	-0.0008	0.0023
411	-0.0010	-0.0010	0.0021	0.0003	0.0003	0.0000	-0.0008	-0.0008	0.0005
412	-0.0010	-0.0010	0.0004	0.0003	0.0003	0.0010	-0.0008	-0.0008	0.0025
413	-0.0010	-0.0010	0.0001	0.0003	0.0003	0.0013	-0.0008	-0.0008	0.0009
414	-0.0009	-0.0009	0.0003	0.0003	0.0003	0.0010	-0.0008	-0.0008	0.0028
415	-0.0009	-0.0009	0.0002	0.0003	0.0003	0.0001	-0.0008	-0.0008	0.0012
416	-0.0009	-0.0009	0.0003	0.0003	0.0003	0.0002	-0.0008	-0.0008	0.0011
417	-0.0008	-0.0008	0.0002	0.0003	0.0003	0.0005	-0.0008	-0.0008	0.0019
418	-0.0008	-0.0008	0.0003	0.0003	0.0003	0.0001	-0.0008	-0.0008	0.0009
419	-0.0008	-0.0008	0.0007	0.0002	0.0002	0.0003	-0.0008	-0.0008	0.0012
420	-0.0007	-0.0007	0.0001	0.0002	0.0002	0.0001	-0.0009	-0.0009	0.0007
421	-0.0007	-0.0007	0.0005	0.0002	0.0002	0.0007	-0.0009	-0.0009	0.0009
422	-0.0007	-0.0007	0.0007	0.0002	0.0002	0.0003	-0.0009	-0.0009	0.0001
423	-0.0006	-0.0006	0.0005	0.0002	0.0002	0.0007	-0.0009	-0.0009	0.0028
424	-0.0006	-0.0006	0.0005	0.0002	0.0002	0.0013	-0.0009	-0.0009	0.0000
425	-0.0006	-0.0006	0.0007	0.0002	0.0002	0.0001	-0.0009	-0.0009	0.0026
426	-0.0005	-0.0005	0.0001	0.0002	0.0002	0.0007	-0.0009	-0.0009	0.0020
427	-0.0005	-0.0005	0.0007	0.0002	0.0002	0.0021	-0.0009	-0.0009	0.0008
428	-0.0004	-0.0004	0.0006	0.0001	0.0001	0.0018	-0.0009	-0.0009	0.0017
429	-0.0004	-0.0004	0.0010	0.0001	0.0001	0.0018	-0.0009	-0.0009	0.0000
430	-0.0004	-0.0004	0.0010	0.0001	0.0001	0.0004	-0.0010	-0.0010	0.0005
431	-0.0003	-0.0003	0.0014	0.0001	0.0001	0.0000	-0.0009	-0.0009	0.0011
432	-0.0003	-0.0003	0.0010	0.0000	0.0000	0.0005	-0.0009	-0.0009	0.0026
433	-0.0002	-0.0002	0.0022	0.0000	0.0000	0.0080	-0.0009	-0.0009	0.0017

434	-0.0002	-0.0002	0.0021	0.0000	0.0000	0.0005	-0.0009	-0.0009	0.0024
435	-0.0001	-0.0001	0.0038	-0.0001	-0.0001	0.0012	-0.0008	-0.0008	0.0024
436	0.0000	0.0000	0.0006	-0.0001	-0.0001	0.0002	-0.0007	-0.0007	0.0001
437	0.0000	0.0000	0.0007	-0.0002	-0.0002	0.0007	-0.0007	-0.0007	0.0004
438	0.0000	0.0000	0.0001	-0.0002	-0.0002	0.0003	-0.0005	-0.0005	0.0007
439	0.0001	0.0001	0.0000	-0.0002	-0.0002	0.0009	-0.0004	-0.0004	0.0003
440	0.0001	0.0001	0.0002	-0.0003	-0.0003	0.0009	-0.0002	-0.0002	0.0002
441	0.0001	0.0001	0.0000	-0.0003	-0.0003	0.0011	-0.0001	-0.0001	0.0014
785	-0.0001	-0.0001	0.0006	0.0000	0.0000	0.0000	-0.0003	-0.0003	0.0014
786	-0.0001	-0.0001	0.0004	0.0000	0.0000	0.0005	-0.0003	-0.0003	0.0002
787	0.0000	0.0000	0.0014	0.0000	0.0000	0.0008	-0.0004	-0.0004	0.0004
788	0.0000	0.0000	0.0009	0.0000	0.0000	0.0005	-0.0005	-0.0005	0.0003
789	0.0000	0.0000	0.0007	0.0000	0.0000	0.0012	-0.0005	-0.0005	0.0003
790	0.0000	0.0000	0.0014	0.0000	0.0000	0.0010	-0.0006	-0.0006	0.0003
791	0.0000	0.0000	0.0001	0.0000	0.0000	0.0082	-0.0006	-0.0006	0.0003
792	0.0001	0.0001	0.0005	0.0000	0.0000	0.0014	-0.0006	-0.0006	0.0002
793	0.0001	0.0001	0.0001	0.0000	0.0000	0.0008	-0.0006	-0.0006	0.0003
794	0.0001	0.0001	0.0007	0.0000	0.0000	0.0047	-0.0007	-0.0007	0.0001
795	0.0001	0.0001	0.0005	0.0000	0.0000	0.0026	-0.0007	-0.0007	0.0005
796	0.0001	0.0001	0.0007	0.0000	0.0000	0.0038	-0.0007	-0.0007	0.0003
797	0.0001	0.0001	0.0000	0.0000	0.0000	0.0009	-0.0007	-0.0007	0.0003
798	0.0001	0.0001	0.0002	0.0000	0.0000	0.0001	-0.0007	-0.0007	0.0002
799	0.0001	0.0001	0.0006	0.0000	0.0000	0.0004	-0.0007	-0.0007	0.0004
800	0.0001	0.0001	0.0004	0.0000	0.0000	0.0037	-0.0007	-0.0007	0.0001
801	0.0001	0.0001	0.0007	0.0000	0.0000	0.0010	-0.0007	-0.0007	0.0003
802	0.0001	0.0001	0.0007	0.0000	0.0000	0.0012	-0.0007	-0.0007	0.0000
803	0.0001	0.0001	0.0003	0.0000	0.0000	0.0008	-0.0007	-0.0007	0.0002
804	0.0001	0.0001	0.0007	0.0000	0.0000	0.0022	-0.0007	-0.0007	0.0000
805	0.0001	0.0001	0.0005	0.0000	0.0000	0.0029	-0.0006	-0.0006	0.0001
806	0.0001	0.0001	0.0002	0.0000	0.0000	0.0017	-0.0006	-0.0006	0.0004
807	0.0001	0.0001	0.0008	0.0000	0.0000	0.0032	-0.0006	-0.0006	0.0002
808	0.0001	0.0001	0.0008	0.0000	0.0000	0.0063	-0.0006	-0.0006	0.0000
809	0.0001	0.0001	0.0008	0.0000	0.0000	0.0063	-0.0006	-0.0006	0.0005
810	0.0000	0.0000	0.0007	0.0000	0.0000	0.0244	-0.0006	-0.0006	0.0004
811	0.0000	0.0000	0.0010	0.0000	0.0000	0.0123	-0.0006	-0.0006	0.0003
812	0.0000	0.0000	0.0005	0.0000	0.0000	0.0017	-0.0006	-0.0006	0.0004
813	0.0000	0.0000	0.0009	0.0000	0.0000	0.0018	-0.0006	-0.0006	0.0004
814	0.0000	0.0000	0.0009	0.0000	0.0000	0.0019	-0.0006	-0.0006	0.0004
815	0.0000	0.0000	0.0012	0.0000	0.0000	0.0008	-0.0006	-0.0006	0.0002
816	0.0000	0.0000	0.0003	0.0000	0.0000	0.0001	-0.0006	-0.0006	0.0002
817	0.0000	0.0000	0.0010	0.0000	0.0000	0.0007	-0.0006	-0.0006	0.0004
818	0.0000	0.0000	0.0014	0.0000	0.0000	0.0006	-0.0006	-0.0006	0.0003
819	0.0000	0.0000	0.0006	0.0000	0.0000	0.0007	-0.0006	-0.0006	0.0002
820	0.0000	0.0000	0.0003	0.0000	0.0000	0.0003	-0.0006	-0.0006	0.0002
821	-0.0001	-0.0001	0.0006	0.0000	0.0000	0.0000	-0.0006	-0.0006	0.0005
822	-0.0001	-0.0001	0.0002	0.0000	0.0000	0.0008	-0.0006	-0.0006	0.0005
823	-0.0001	-0.0001	0.0001	0.0000	0.0000	0.0007	-0.0007	-0.0007	0.0001
824	-0.0001	-0.0001	0.0023	0.0000	0.0000	0.0001	-0.0007	-0.0007	0.0000

825	-0.0001	-0.0001	0.0024	0.0000	0.0000	0.0009	-0.0007	-0.0007	0.0001
826	-0.0001	-0.0001	0.0041	0.0000	0.0000	0.0009	-0.0008	-0.0008	0.0023
827	-0.0001	-0.0001	0.0001	-0.0001	-0.0001	0.0013	-0.0008	-0.0008	0.0012
828	-0.0001	-0.0001	0.0003	-0.0002	-0.0002	0.0009	-0.0008	-0.0008	0.0009
829	0.0000	0.0000	0.0012	-0.0003	-0.0003	0.0003	-0.0008	-0.0008	0.0025
830	0.0001	0.0001	0.0005	-0.0004	-0.0004	0.0002	-0.0008	-0.0008	0.0017
831	0.0001	0.0001	0.0032	-0.0005	-0.0005	0.0004	-0.0006	-0.0006	0.0002
832	0.0002	0.0002	0.0006	-0.0007	-0.0007	0.0003	-0.0004	-0.0004	0.0008
833	0.0002	0.0002	0.0018	-0.0009	-0.0009	0.0020	-0.0003	-0.0003	0.0004
Avg:			**0.0010**			**0.0015**			**0.0007**

4.2 Contour Plots

(1) Displacement Contours:

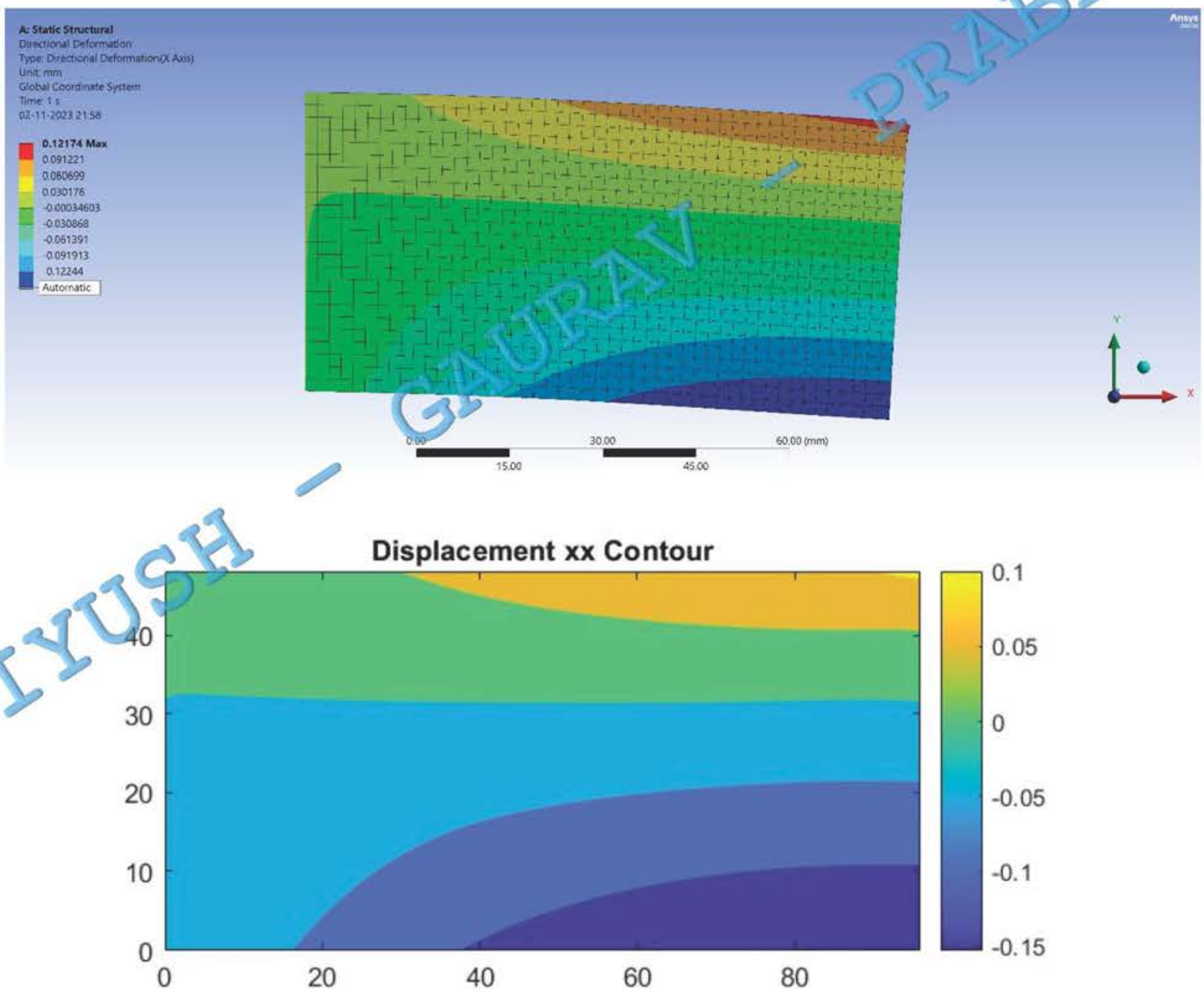


Fig 4.1 Contour of Displacement in X-Direction in ANSYS and MATLAB

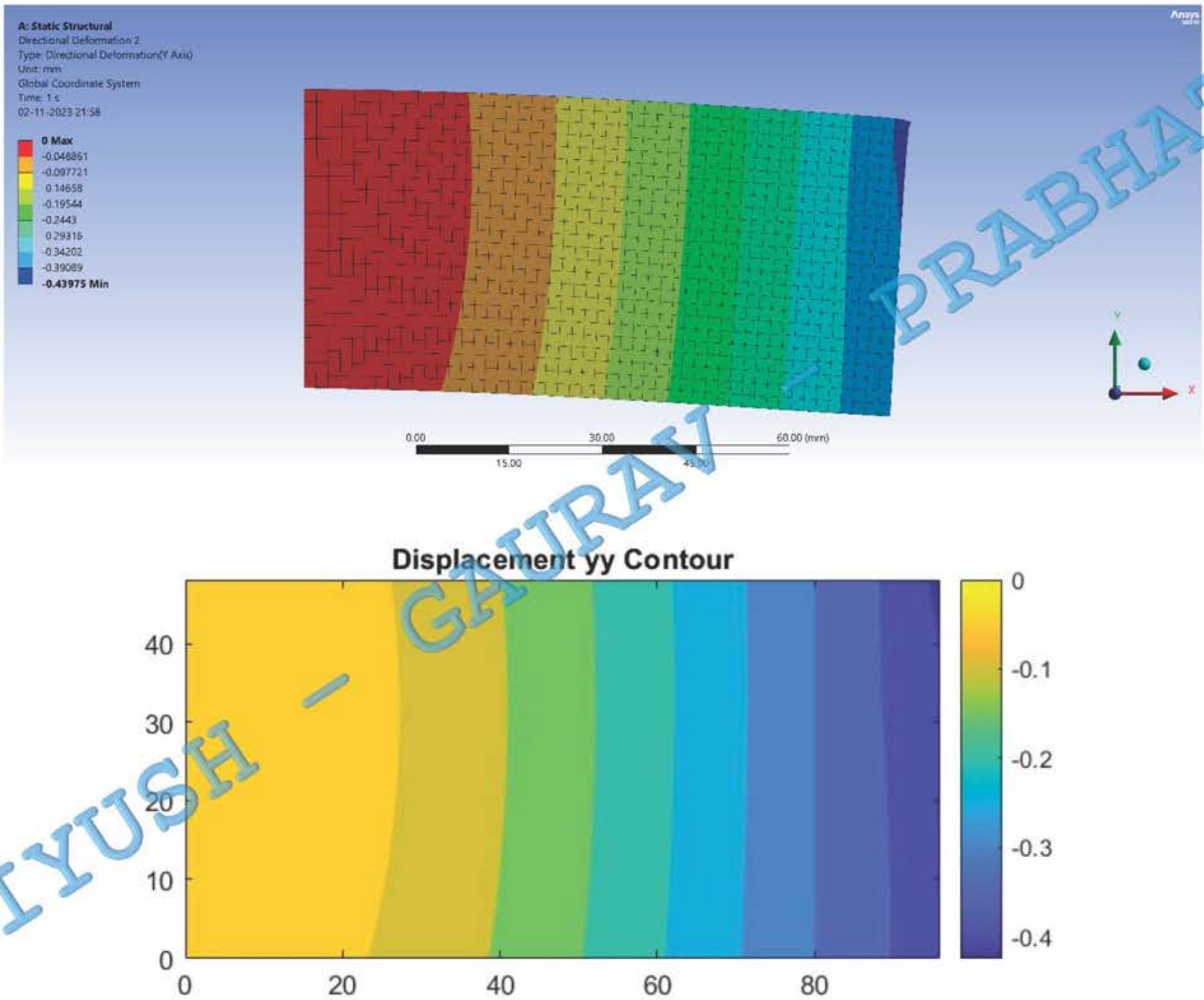


Fig 4.2 Contour of Displacement in Y-Direction in ANSYS and MATLAB

(2) Stress Contours:

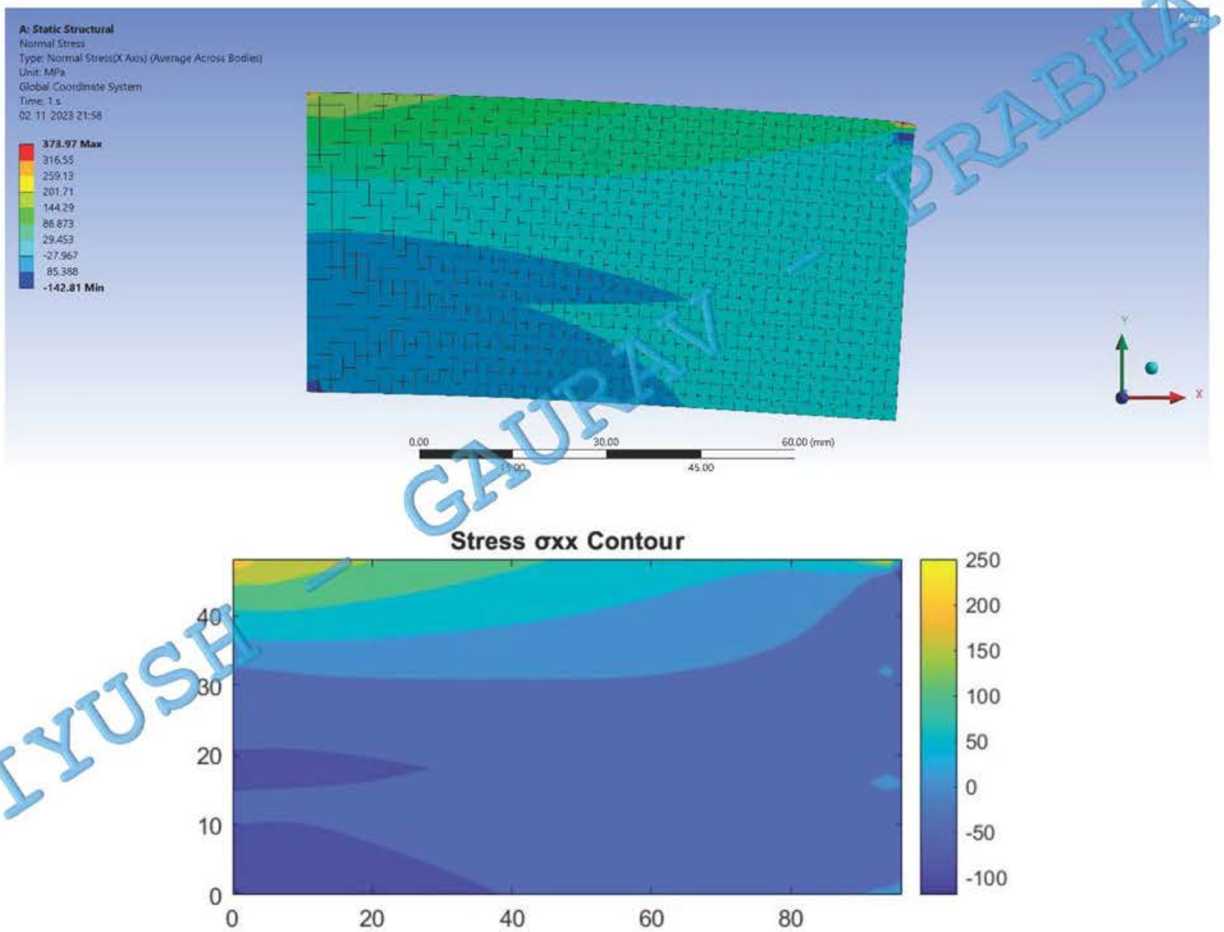


Fig 4.3 Contour of Normal Stress in X-Direction in ANSYS and MATLAB

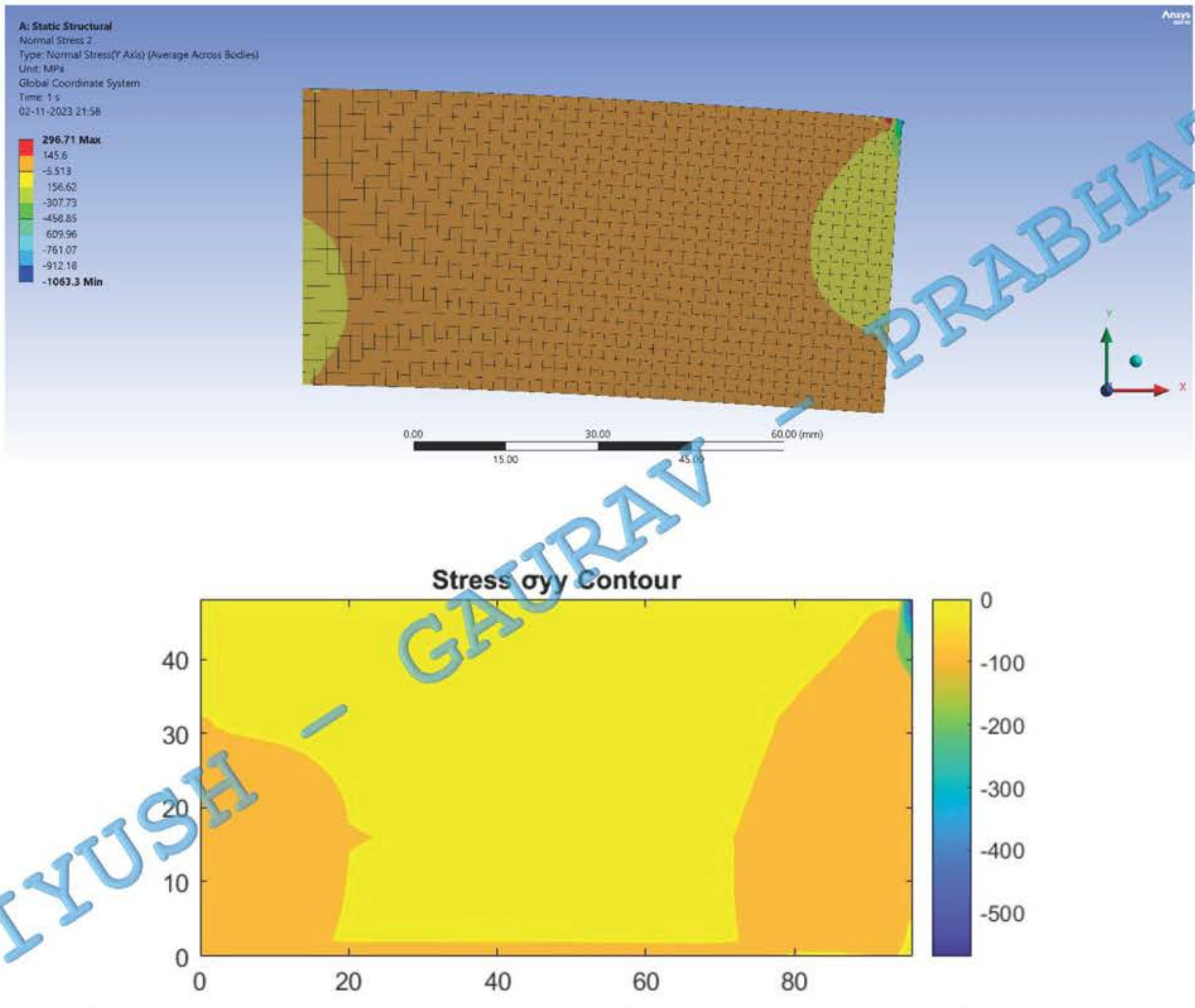


Fig 4.4 Contour of Normal Stress in Y-Direction in ANSYS and MATLAB

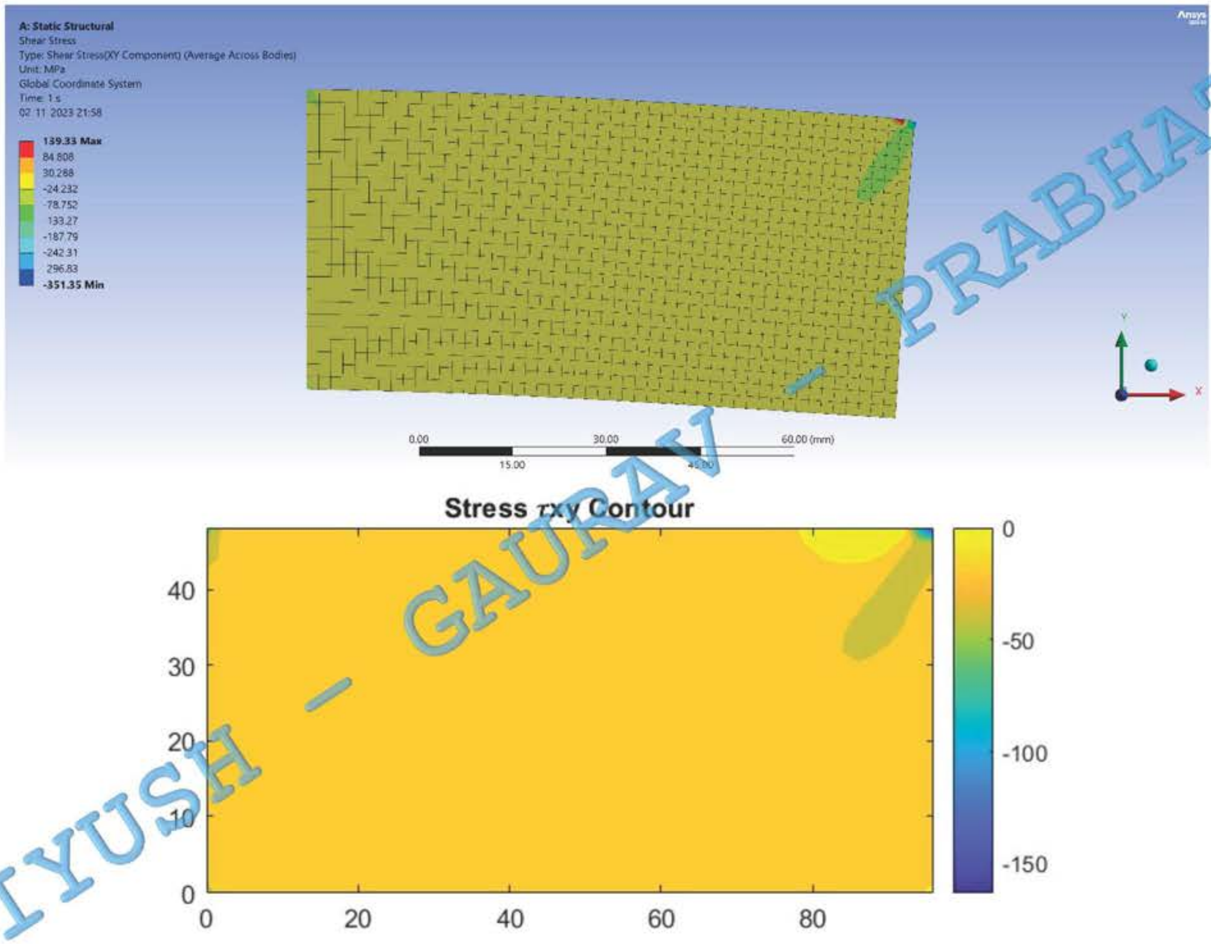
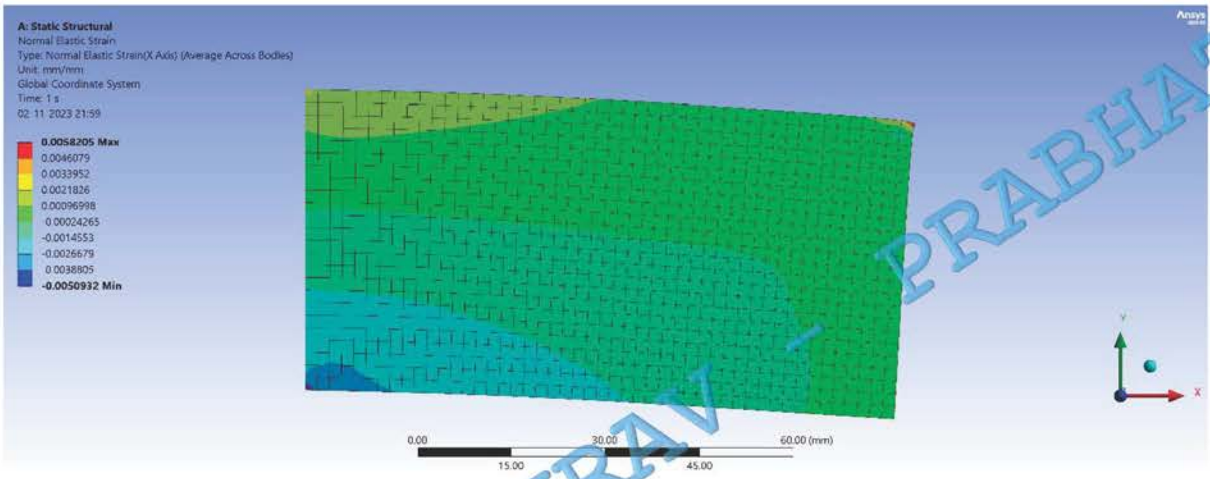


Fig 4.5 Contour of Shear Stress in XY-Direction in ANSYS and MATLAB

(3) Strain Contours:



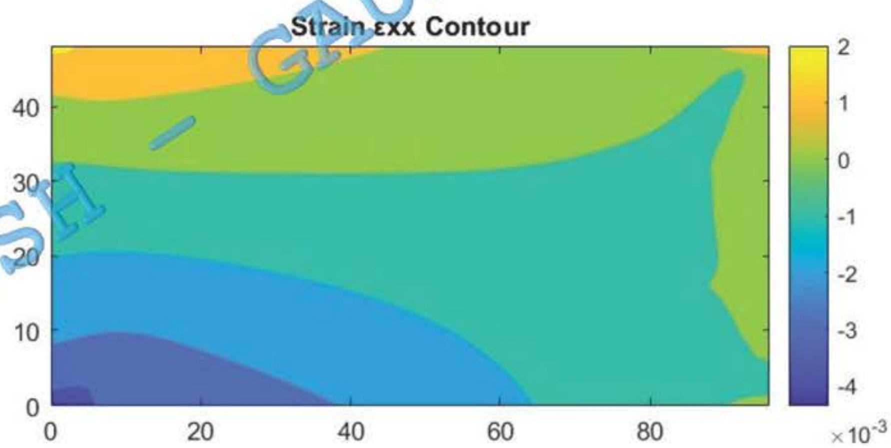


Fig 4.6 Contour of Normal Strain in X-Direction in ANSYS and MATLAB

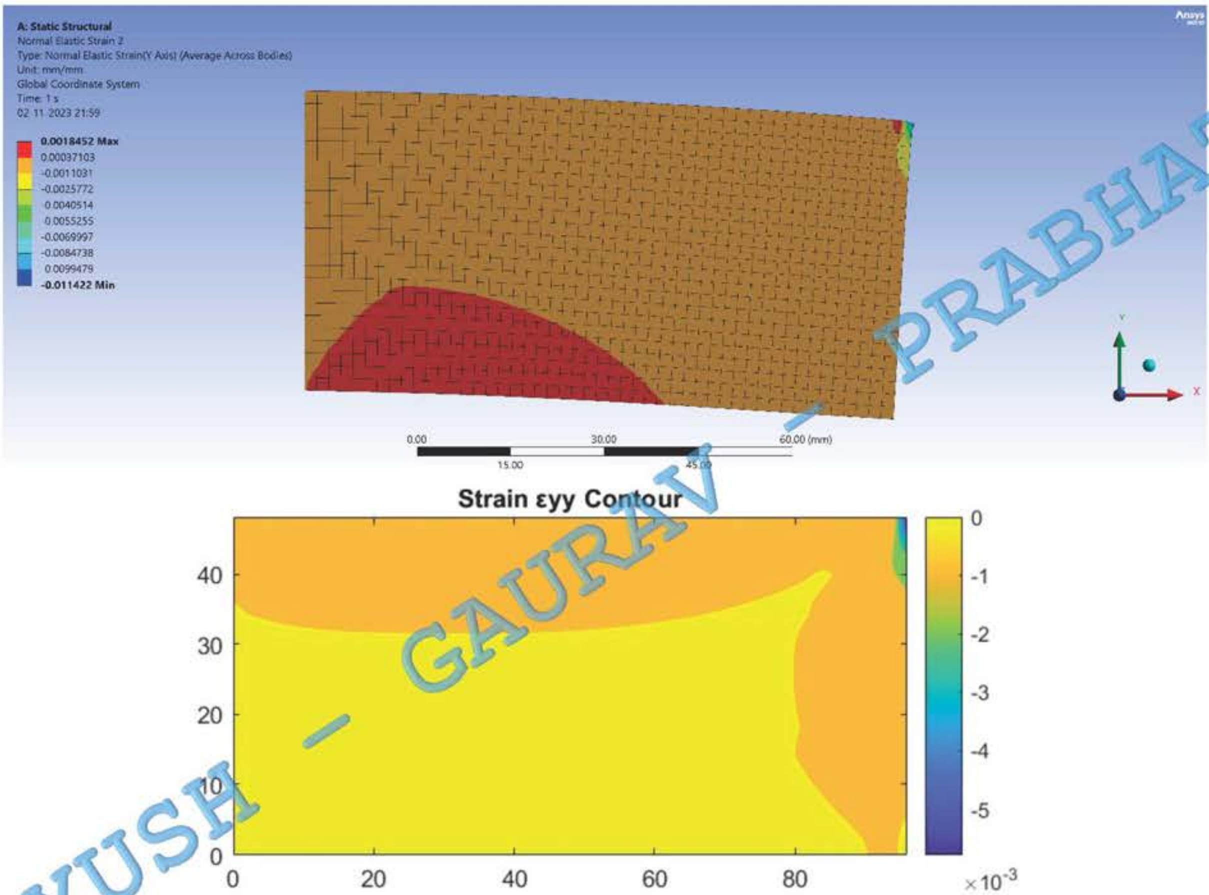


Fig 4.7 Contour of Normal Strain in Y-Direction in ANSYS and MATLAB

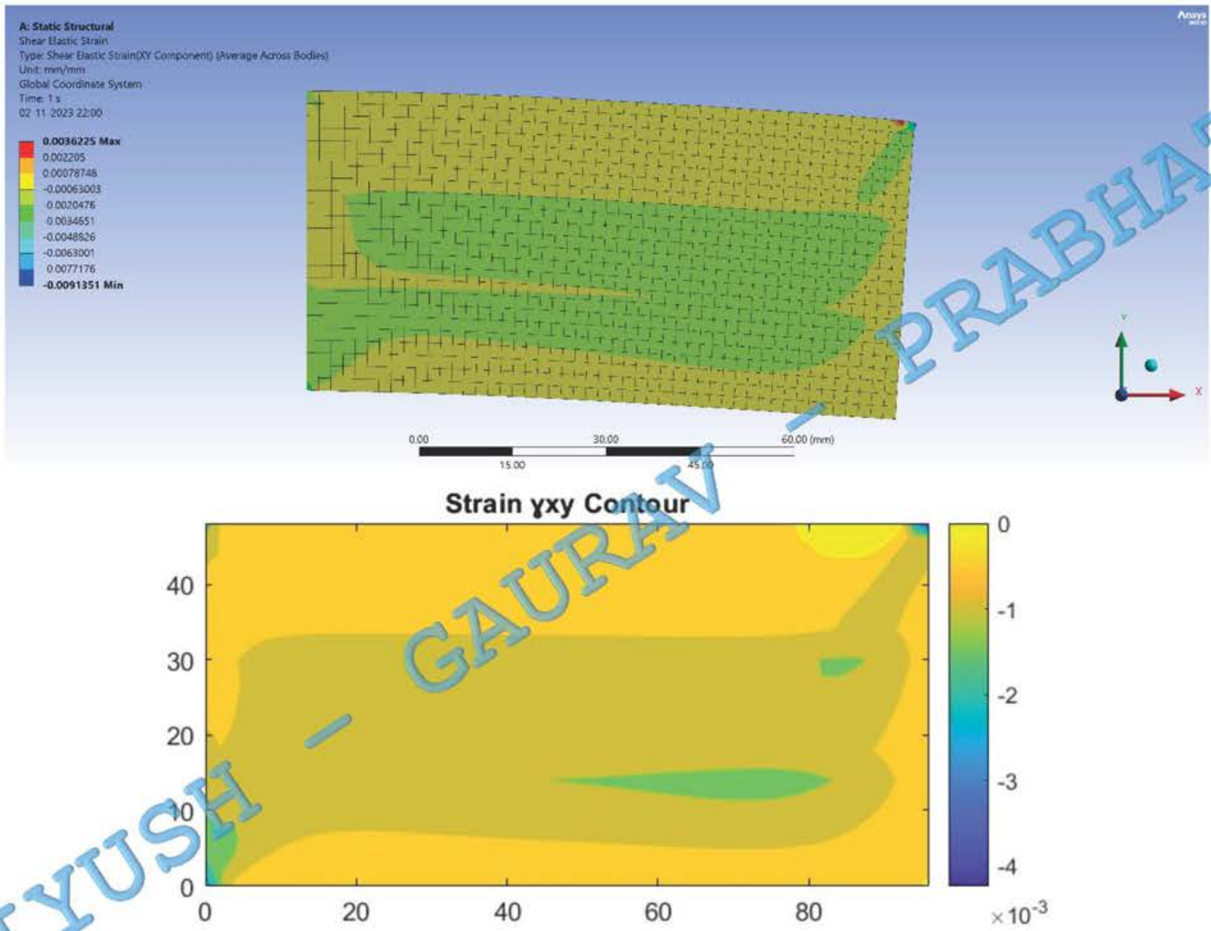


Fig 4.8 Contour of Shear Strain in XY-Direction in ANSYS and MATLAB

4.3 Error Calculation

Sr	Parameter	Absolute % Error between MATLAB & ANSYS results
1	Displacement-X	0.000850
2	Displacement-Y	0.000839
3	Normal Stress-X	0.000981
4	Normal Stress-Y	0.012390
5	Shear Stress-XY	0.001040
6	Normal Strain-X	0.001011
7	Normal Strain-Y	0.001516
8	Shear Strain-XY	0.000684

CHAPTER 5

CONCLUSION

1) Results obtained from MATLAB code validated through ANSYS results. Both results matching with error less than 0.015%.
2) Due to load at a corner node/edge, stress is concentrated on the edge. So, stress results near point of application of load are not compared in this case due to slight decrement in accuracy of results near it.
3) Convergence Test is done in MATLAB using square elements which gives following results for max displacements which indicates maximum horizontal displacement is converging at 0.1529 mm (showing convergence up to 4th decimal) and maximum vertical deflection still has scope of convergence after 0.4379 mm (due to limitations of software/RAM).

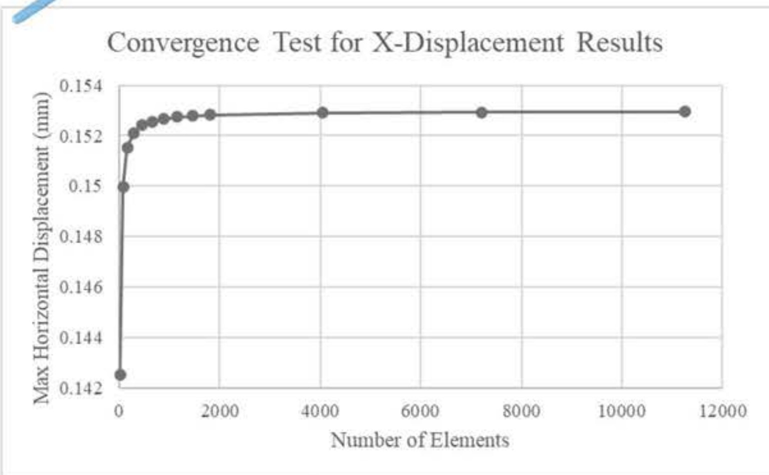


Fig 5.1 Convergence Test for Maximum X-Displacement in MATLAB

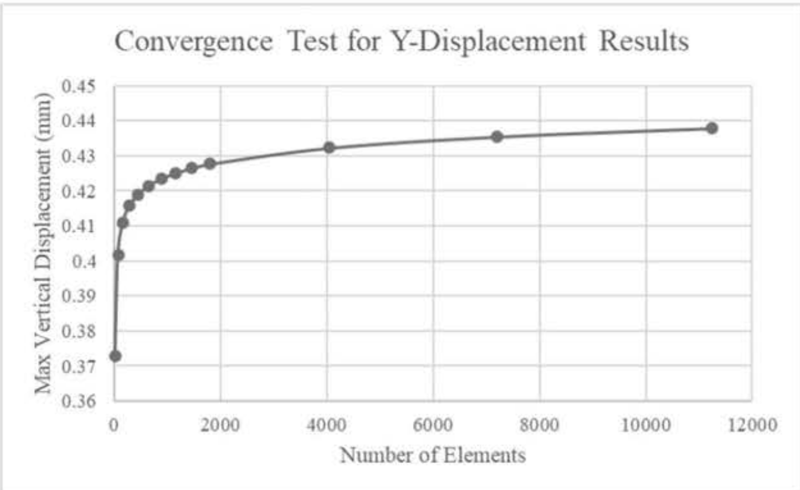


Fig 5.2 Convergence Test for Maximum Y-Displacement in MATLAB

CHAPTER 6

REFERENCES

1) K.M. Entwistle, "Basic Principles of the Finite Element Method," 1st Edition - 1 January 1999.
2) Ferreira Antonio J. M., "MATLAB Codes for Finite Element Analysis," 2nd Edition, 2009